

UNCLASSIFIED

AD 4 4 3 9 8 5

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

443985

FOR OFFICIAL USE ONLY

443985

R 322

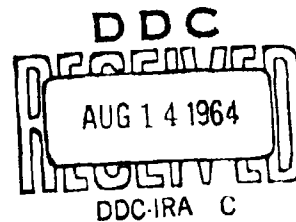
Technical Report

THERMOELECTRIC-GENERATOR SYSTEMS
FOR EMERGENCY SHELTERS

14 July 1964



U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California



THERMOELECTRIC-GENERATOR SYSTEMS FOR EMERGENCY SHELTERS

Y-F011-05-02-346

Type B Final Report

by

Douglas Taylor

ABSTRACT

A study was conducted to determine the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small emergency shelters. Such systems were found feasible, and costs for a family-size and a 100-man shelter are given. Comparative merits and costs of other suitable systems are also given.

Qualified requesters may obtain copies of this report from DDC.
The Laboratory invites comment on this report, particularly on the
results obtained by those who have applied the information.

INTRODUCTION

It is generally assumed that if the United States became involved in a general war, nuclear weapons would be used and, as a result, the nation's governmental and industrial facilities would be seriously damaged. There would be a sudden retreat of the citizenry to emergency shelters to avoid radioactive fallout, and it would be a week or two in some areas before radiation would be reduced to a safe level. In the meantime, the morale and possibly the lives of the refugees would depend to a great extent upon the adequacy of their shelters.

A series of tasks has been initiated by the Bureau of Yards and Docks to provide shelter inhabitants with some of the more essential elements for living.

The objective of this task was to investigate the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small shelters. As part of this, the possibility of providing ventilation through the chimney effect produced by the flame was to be considered. The task instruction extended the objective to the investigation of other possible applications of thermoelectric power supplies in shelters, and if feasible, to the development of suitable prototypes in a later phase of the task.

BACKGROUND

In 1961, at the peak of the renaissance in thermoelectric research and development, NCEL made a survey to determine if any of the new thermoelectric devices would fit the requirements of the Bureau of Yards and Docks. Thermoelectric generators were found to have low efficiency and they were considered economically feasible only where efficiency or initial cost was not a prime consideration.¹

Many of the thermoelectric generators under development at the time of the survey have been completed and tested. They have shown an improvement over earlier devices in life and reliability because of the following changes:

1. Improvement of the thermocouple alloys and of the methods for fabricating the elements.

2. Optimization of the size of the usually brittle elements to reduce the stresses introduced by the difference in temperature from the hot to the cold side.
3. Introduction of materials and methods to reduce sublimation and degradation of elements.

There has also been a slight improvement in the overall efficiency of thermoelectric generators due to the following:

1. Reduction of resistance losses by improvement of contacts between the couple elements and the hot and cold plates.
2. Increase in the temperature difference between the hot and cold plates by the use of better thermal insulation.

Individual thermocouples with 6-percent efficiency have been reported, and where the losses in burners or other thermocouple heating methods are not considered, efficiencies of 10 percent are mentioned. However, researchers are still striving for actual efficiencies nearer the theoretical 25 percent that seems available. Presently, the overall efficiency of propane generators (fuel in to power out), which is the most important criterion, is below 3 percent (see Table I). The mechanical development of thermoelectric generators appears to have reached a peak, and further increase in generator efficiency awaits the discovery of better thermoelectric elements.

FINDINGS

The theoretical aspect of ventilating emergency shelters by chimney effect has been reported. It was determined that the horsepower requirement for moving the air supply for a family-size shelter and a 100-man shelter for a period of two weeks would be low. Thus conditions would be favorable for the use of a thermoelectric power source.² Furthermore, thermoelectric power has been deemed justified (notwithstanding the high cost of the generators and their output) where the conventional public utility power source is not available.¹ However, the advantages and disadvantages of other, more common, emergency power sources should be considered in comparison to a thermoelectric source.

Thermoelectric Power Source for Family-Size Shelters

Commercial thermoelectric generators are now available off the shelf and are adequate for the power requirements of family-size shelters. They are portable and reliable, quiet, have no moving parts, and need no maintenance. They have not been

on the market long enough to determine shelf life, but it appears that they should last 10 years without deterioration and be ready instantly to generate power if there is a fuel supply. However, they are costly under present production standards. A typical installation (with approximate costs) would include a 12-volt, 12-watt generator installed near the shelter exhaust stack (\$350); a 60-pound-capacity propane storage tank (\$25); a pressure regulator (\$4); a pipe and shut-off valve (\$4); electrical wiring, a dome-light fixture, and a No. 1003 or 1004, 15-candlepower, 12-watt electric lamp (\$7). The total cost of these parts is \$390, and installation labor would increase the cost to about \$500. One tank of propane, 14.2 gallons (\$4), would supply fuel for 400 hours at 80 cents per kilowatt-hour compared to 3 to 4 cents from a public utility.

The generator's burner can use butane or natural gas when the orifice is changed. Both propane and butane are heavier than air, so that a leaky system would create an explosive hazard, particularly in basement or underground shelters. Natural gas would probably not be available in the emergency. The generator would need to be modified to burn liquid fuels. In all cases, the fuel tank would require periodic checks to assure that it was full for the emergency.

The propane burner produces 3200 Btu per hour, and the generator's overall efficiency is only 1.27 percent. Therefore, most of the heat would be rejected to the stack and would augment the gravity flow of air for shelter ventilation through chimney effect.

An alternate secondary circuit for this installation could include a No. 57, 2-candlepower, 3.4-watt electric lamp; a light fixture; and a 2-inch, 12,000-rpm fan which consumes 5 watts and delivers air at 31 cfm.

The dome light in the primary circuit would be good for reading at 3 feet from the source and poor at 6 feet. With the dome light off, the secondary circuit could provide the minimum essential illumination to see objects within the shelter and would supplement further the flow of air for ventilation.

More elaborate arrangements could be assembled for this thermoelectric power system. It could be arranged to trickle-charge a battery when the lights and fan are off. A transistorized 12-volt transceiver, walkie-talkie, or intercom set could be installed.

The LP-gas supply could be used for a stove, an absorption-type refrigerator, and for a mantle-type lamp to provide brilliant illumination. This gas lamp would be used as the primary source of light, and the heat generated could supplement the gravity ventilation if the lamp were properly placed near the shelter exhaust stack. Although it appears that the LP-gas supply alone could provide adequate services to a shelter,

there are wind and temperature conditions where the induced gravity flow of air would be inadequate,³ and a thermoelectric generator and fan combination would be desirable to provide a forced-draft ventilation system.

Thermoelectric Power Source for a 100-Man Shelter

The thermoelectric generators that are suitable for a 100-man shelter were developed under Government contracts. The 250-watt "Man-Pack" thermoelectric generator, produced under BuShips Contract NObs-78198, could be an effective installation, which would include two 60-watt lights and a 1/6-hp, 700-cfm ventilating fan. The contractor believes that similar thermoelectric generators in 100-unit lots can be fabricated for \$4800 each, and that full production would reduce this cost substantially. A complete shelter installation would cost up to \$5500.

The generator is 18-1/2 inches long, 15 inches wide, 10-1/4 inches high, and weighs about 40 pounds.⁴ It uses about 570 pounds of propane for two weeks of operation. Two standard 300-pound-capacity storage tanks would be required for the emergency period. With fuel at 6.37 cents per pound (27 cents per gallon), it would cost 42 cents per kilowatt-hour. A more elaborate installation with a communication system, stove, LP-gas refrigerator, and better illumination could use two "Man-Packs."

The operating data for several propane-fueled thermoelectric generators are given in Table I. Most of these generators can be changed to use other gas fuels, and probably could be modified to use liquid fuels.

Other Power Sources for Shelters

Several other power sources are readily available and are noted here only for comparison to the thermoelectric source.

An LP-gas, pressure-gasoline, or kerosene gas-mantle lamp would provide ample light for a family-size shelter. It would be located near the shelter exhaust stack so that the heat from the mantle flame would aid the flow of air for ventilation. A burner could be placed in the stack for a greater flow, although it may prove inadequate under certain wind and temperature conditions. A complete system could be assembled for \$75 to \$100. It would have a long shelf life and would be reliable. The kerosene unit would be quiet and relatively safe. The LP-gas and pressure-gasoline units would create a hissing noise that might be objectionable, and there are greater explosion and asphyxiation hazards with these units. Extra mantles would need to be stored to replace the brittle failures which are common in used mantles. The system would require periodic checks to assure

that it was ready for emergency use; otherwise, it could be considered maintenance free. A single-light system might also be suitable for a 100-man shelter. Multiple lights would not be recommended because they would use too much oxygen and would generate too much heat and other by-products.

A battery and standard trickle-charger system, equivalent to the thermoelectric system for a family-size shelter, could be assembled for \$100 to \$150. It would have a shelf life of 5 to 10 years, would be ready for instant use, and would be quiet and reliable in operation. However, a periodic check of the battery-acid level and charge would be required to assure that it was ready for any emergency, and adequate ventilation would be needed to eliminate battery gas and odor. A similar battery and trickle-charger system to provide light and augment the ventilation for a 100-man shelter would cost about \$3000.

The smallest of reliable engine-generator sets, suitable for continuous use over a 2-week period, would provide more than ample power to light and ventilate a family-size shelter, and would probably meet the minimum requirements of a 100-man shelter. A system built around this generator set would cost about \$200 for the small shelter and \$400 for the larger shelter. However, engine-generator sets cannot be stored for long periods unless preserved; therefore, they would not be ready to operate at a moment's notice. They also create noise, heat, and odor when operated, so they are less desirable than the other power sources.

CONCLUSIONS

1. The use of thermoelectric-generator systems to provide power for lighting emergency shelters is feasible.
2. Thermoelectric generators are costly under present production standards. The cost could probably be reduced substantially in a full production line.
3. A thermoelectric-generator system would have a long shelf life, would be quiet and reliable in operation, and would be free from maintenance.
4. Thermoelectric generators suitable for emergency shelters are available off the shelf or from existing Government-contracted designs; therefore, no further development is needed at this time. It may be desirable to convert the burners so that a fuel less hazardous than propane can be used.
5. There are other power sources that are reliable, quiet, efficient, economical, and maintenance free.

Table I. Propane-Fueled Thermoelectric Generators

Watts Output	Volts dc	Fuel Rate (lb/hr)	Overall Efficiency (%)	Fuel Cost (\$/kw-hr) ¹	Cooling Method	Weight (lb)	Builder ²
344	60.2	1.98	2.75	0.37	Fans	36	3M ⁵
250	60	1.7	2.42	0.42	Fans	38	3M ⁴
100	9	0.9	2.4	0.57	Natural Convection	47	Westinghouse ⁶
30	6	0.30	1.6	0.64	↓	60	3M ⁷
12	12	0.15	1.27	0.80		32	3M ⁸
8.3	1.5	0.14	0.95	1.02		not given	Texas Instruments ⁹
6	12	0.08	0.85	0.85		19	3M ⁸
2.9	12	0.08	0.6	1.75		not given	General Instrument
2.4	12	0.05	0.76	1.35		15	3M ⁸

¹/ Based on delivered price of propane at NCEL: 27 cents per gallon.

²/ Numbers after builders' identifications are references.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Report R-142: Potential of thermoelectric devices in BuDocks applications, by D. Taylor and J. J. Doman. Port Hueneme, Calif., 13 Apr. 1961.
2. U. S. Naval Civil Engineering Laboratory. Technical Note N-471: Gravity ventilation of protective shelters, by E. J. Beck. Port Hueneme, Calif., 8 July 1963.
3. U. S. Naval Civil Engineering Laboratory. Technical Report: Gravity ventilation of protective shelters, by J. C. King. Port Hueneme, Calif. (to be published.)
4. 3M Minnesota Mining and Manufacturing Company. Product Information Bulletin E-TEGMP(72.03)R, 250 watt "Man-Pack" generator. St Paul, Minn.
5. U. S. Naval Research Laboratory. Memorandum Report 1361: Status report on thermoelectricity, part 2, Devices, by J. W. Davisson and Joseph Pasternak. Washington, D. C., Jan. 1963.
6. U. S. Air Force. Rome Air Development Center. Report No. RADC-TN-61-26: Performance of the TAP-100 thermoelectric converter, by John E. McCormick. Griffiss Air Force Base, New York, Apr. 1961. AD 257312.
7. 3M Minnesota Mining and Manufacturing Company. Product Information Bulletin E-TEGPI(72.03)R. Thermoelectric generator. St. Paul, Minn.
8. 3M Minnesota Mining and Manufacturing Company. Product Information Bulletin E-TEGFB(23.5)JR. Thermoelectric generators. St. Paul, Minn.
9. U. S. Coast Guard Testing and Development Division. Report No. 320: Thermoelectric power supplies for aids to navigation. Washington, D. C., 15 Jan. 1963.

DISTRIBUTION LIST

SNDL Code	No. of Activities	Total Copies	
	1	10	Chief, Bureau of Yards and Docks (Code 42)
23A	1	1	Naval Forces Commanders (Taiwan only)
39B	2	3	Construction Battalions
39D	5	5	Mobile Construction Battalions
39E	3	3	Amphibious Construction Battalions
39F	1	2	Construction Battalion Base Units
A2A	1	1	Chief of Naval Research - Only
A3	2	2	Chief of Naval Operation (OP-07, OP-04)
A5	5	5	Bureaus
B3	2	2	Colleges
E4	1	2	Laboratory ONR (Washington, D. C. only)
E5	1	1	Research Office ONR (Pasadena only)
E16	1	1	Training Device Center
F9	7	7	Station - CNO (Boston; Key West; San Juan; Long Beach; San Diego; Treasure Island; and Rodman, C. Z. only)
F17	6	6	Communication Station (San Juan; San Francisco; Pearl Harbor; Adak, Alaska; and Guam only)
F41	1	1	Security Station
F42	1	1	Radio Station (Oso and Cheltenham only)
F48	1	1	Security Group Activities (Winter Harbor only)
F61	2	2	Naval Support Activities (London and Naples only)
F77	1	1	Submarine Base (Groton, Conn. only)
F81	2	2	Amphibious Bases
H3	7	7	Hospital (Chelsea; St. Albans, Portsmouth, Va.; Beaufort; Great Lakes; San Diego; and Camp Pendleton only)
H6	1	1	Medical Center
J1	2	2	Administration Command and Unit - BuPers (Great Lakes and San Diego only)
J3	1	1	U. S. Fleet Anti-Air Warfare Training Center (Virginia Beach only)
J19	1	1	Receiving Station (Brooklyn only)
J34	1	1	Station - BuPers (Washington, D. C. only)

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
J46	1	1	Personnel Center
J48	1	1	Construction Training Unit
J60	1	1	School Academy
J65	1	1	School CEC Officers
J84	1	1	School Postgraduate
J90	1	1	School Supply Corps
J95	1	1	School War College
J99	1	1	Communication Training Center
L1	11	11	Shipyards
L7	4	4	Laboratory - BuShips (New London; Panama City; Carderock; and Annapolis only)
L26	5	5	Naval Facilities - BuShips (Antigua; Turks Island; Barbados; San Salvador; and Eleuthera only)
L42	2	2	Fleet Activities - BuShips
M27	4	4	Supply Center
M28	6	6	Supply Depot (except Guantanamo Bay; Subic Bay; and Yokosuka)
M61	2	2	Aviation Supply Office
N1	6	18	BuDocks Director, Overseas Division
N2	9	27	Public Works Offices
N5	3	9	Construction Battalion Center
N6	5	5	Construction Officer-in-Charge
N7	1	1	Construction Resident-Officer-in-Charge
N9	6	12	Public Works Center
N14	1	1	Housing Activity
R9	2	2	Recruit Depots
R10	2	2	Supply Installations (Albany and Barstow only)
R20	1	1	Marine Corps Schools (Quantico)
R64	3	3	Marine Corps Base
R66	1	1	Marine Corps Comp Detachment (Tongan only)
W1A1	6	6	Air Station
W1A2	35	35	Air Station
W1B	8	8	Air Station Activities

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
W1C	3	3	Air Facility (Phoenix; Naha; and Naples only)
W1E	6	6	Marine Corps Air Station (except Quantico)
W1H	9	9	Station ~ BuWeps (except Rota)
	1	1	Deputy Chief of Staff, Research and Development, Headquarters, U. S. Marine Corps, Washington, D. C.
	1	1	President, Marine Corps Equipment Board, Marine Corps School, Quantico, Va.
	1	1	Chief of Staff, U. S. Army, Chief of Research and Development, Department of the Army, Washington, D. C.
	1	1	Office of the Chief of Engineers, Assistant Chief of Engineering for Civil Works, Department of the Army, Washington, D. C.
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: Engineering Research and Development Division
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: ENG CW-OE
	1	1	Director, U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va., Attn: Information Resources Branch
	1	3	Headquarters, U. S. Air Force, Directorate of Civil Engineering, Washington, D. C., Attn: AFCE-ES
	1	1	Commanding Officer, U. S. Naval Construction Battalion Center, Port Hueneme, Calif., Attn: Materiel Dept., Code 140
	1	1	Deputy Chief of Staff, Development, Director of Research and Development, Department of the Air Force, Washington, D. C.
	1	1	Director, National Bureau of Standards, Department of Commerce, Connecticut Avenue, Washington, D. C.
	1	2	Office of the Director, U. S. Coast and Geodetic Survey, Washington, D. C.
	1	20	Defense Documentation Center, Building 5, Cameron Station, Alexandria, Va.
	1	2	Director of Defense Research and Engineering, Department of Defense, Washington, D. C.
	1	2	Director, Bureau of Reclamation, Washington, D. C.
	1	1	Facilities Officer, Code 108, Office of Naval Research, Washington, D. C.
	1	1	Federal Aviation Agency, Office of Management Services, Administrative Services Division, Washington, D. C., Attn: Library Branch

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	2	Commander Naval Beach Group Two, U. S. Naval Amphibious Base, Little Creek, Norfolk, Va.
1	1	Commander, Pacific Missile Range, Technical Documentation Section, P. O. Box 10, Point Mugu, Calif., Attn: Code 4332
1	2	U. S. Army Engineer Research and Development Laboratories, Attn: STINFO Branch, Fort Belvoir, Va.
1	1	Systems Engineering Group, Deputy for Systems Engineering, Directorate of Technical Publications and Specifications (SEPRR), Wright-Patterson Air Force Base, Ohio
1	1	Office of Civil Defense, Department of Defense, Washington, D. C.

U. S. Naval Civil Engineering Laboratory
Technical Report R-322
THERMOELECTRIC-GENERATOR SYSTEMS FOR
EMERGENCY SHELTERS, by Douglas Taylor
11 p. illus 14 Jul 64 OFFICIAL USE ONLY

A study was conducted to determine the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small emergency shelters. Such systems were found feasible, and costs for a family-size and a 100-man shelter are given. Comparative merits and costs of other suitable systems are also given.

Key Words: thermoelectric; generators; power supply; emergency shelters

1. Shelters, emergency —
Thermoelectric power
I. Taylor, Douglas
II. Y-F011-05-02-346

U. S. Naval Civil Engineering Laboratory
Technical Report R-322
THERMOELECTRIC-GENERATOR SYSTEMS FOR
EMERGENCY SHELTERS, by Douglas Taylor
11 p. illus 14 Jul 64 OFFICIAL USE ONLY

A study was conducted to determine the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small emergency shelters. Such systems were found feasible, and costs for a family-size and a 100-man shelter are given. Comparative merits and costs of other suitable systems are also given.

Key Words: thermoelectric; generators; power supply; emergency shelters

U. S. Naval Civil Engineering Laboratory
Technical Report R-322
THERMOELECTRIC-GENERATOR SYSTEMS FOR
EMERGENCY SHELTERS, by Douglas Taylor
11 p. illus 14 Jul 64 OFFICIAL USE ONLY

A study was conducted to determine the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small emergency shelters. Such systems were found feasible, and costs for a family-size and a 100-man shelter are given. Comparative merits and costs of other suitable systems are also given.

Key Words: thermoelectric; generators; power supply; emergency shelters

1. Shelters, emergency —
Thermoelectric power
I. Taylor, Douglas
II. Y-F011-05-02-346

U. S. Naval Civil Engineering Laboratory
Technical Report R-322
THERMOELECTRIC-GENERATOR SYSTEMS FOR
EMERGENCY SHELTERS, by Douglas Taylor
11 p. illus 14 Jul 64 OFFICIAL USE ONLY

A study was conducted to determine the feasibility of using small flame-activated thermoelectric-generator systems to provide power for lighting small emergency shelters. Such systems were found feasible, and costs for a family-size and a 100-man shelter are given. Comparative merits and costs of other suitable systems are also given.

Key Words: thermoelectric; generators; power supply; emergency shelters

1. Shelters, emergency —
Thermoelectric power
I. Taylor, Douglas
II. Y-F011-05-02-346